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Furuta

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[54] RUN LENGTH ENCODING AND DECODING METHODS AND MEANS

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[*] Notice: The portion of the term of this patent subsequent to Nov. 1, 1994, has been disclaimed.

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[30] Foreign Application Priority Data

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[51] Int. Cl.² H04N 7/12

[52] U.S. Cl. .... 358/133; 358/260; 358/261; 358/262; 325/38 A; 178/68

[58] Field of Search .... 325/38 A; 358/260, 261, 358/133, 262; 178/68; 340/347 DD

[56] References Cited

U.S. PATENT DOCUMENTS

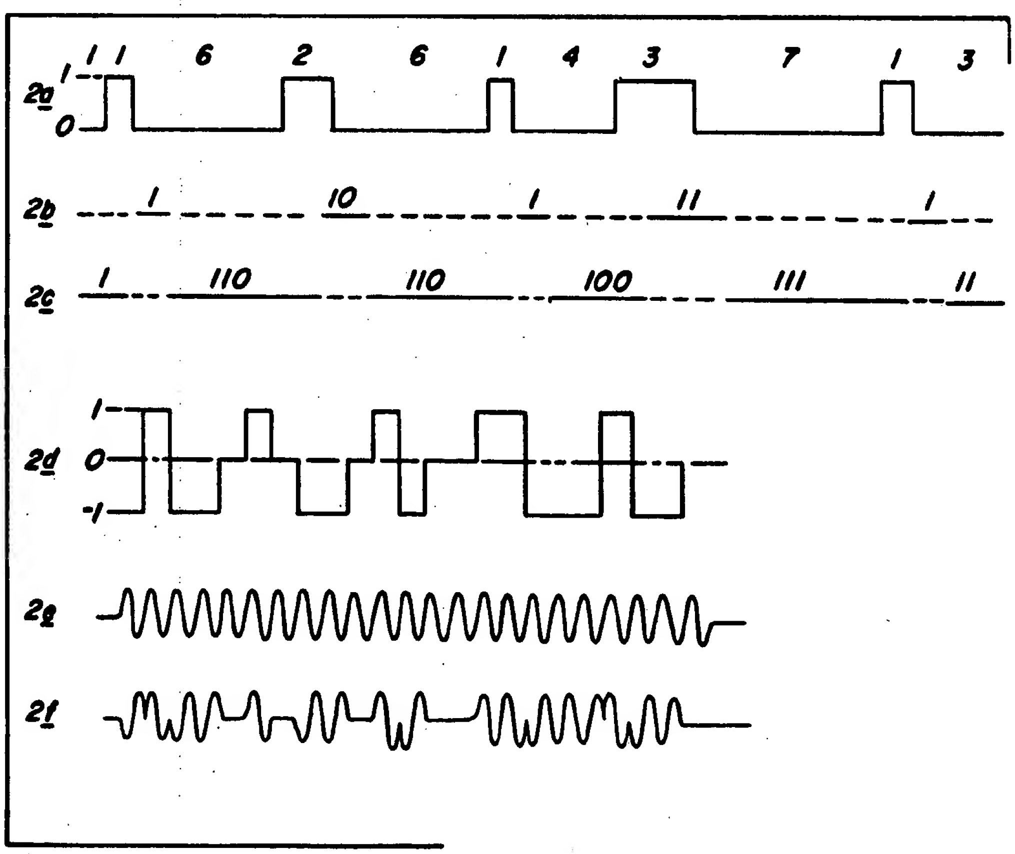
3,233,236	2/1966	Katzenstein	325/38 A
3,337,864	8/1967	Zender	325/38 A
3,502,806	3/1970	Townsend	358/261
3,847,732	11/1974	Perreault	178/68

Primary Examiner—Robert L. Griffin
Assistant Examiner—Edward L. Coles

[57] ABSTRACT

Black and white run length encoding means first convert a binary video input signal having a raster scan format into binary black and white run length message codes which are preselected so that the initial or lead bit of each of those codes is at a given logic level. Ternary encoding means convert the binary message codes into a series of ternary black and white run length message codes which have distinctive amplitude transitions at any intra-scan line code boundaries, and an amplitude sensitive phase modulator then converts the ternary codes into a phase modulated, interrupted carrier passband signal. To recover the video signal from the passband signal, the process is reversed.

7 Claims, 5 Drawing Figures



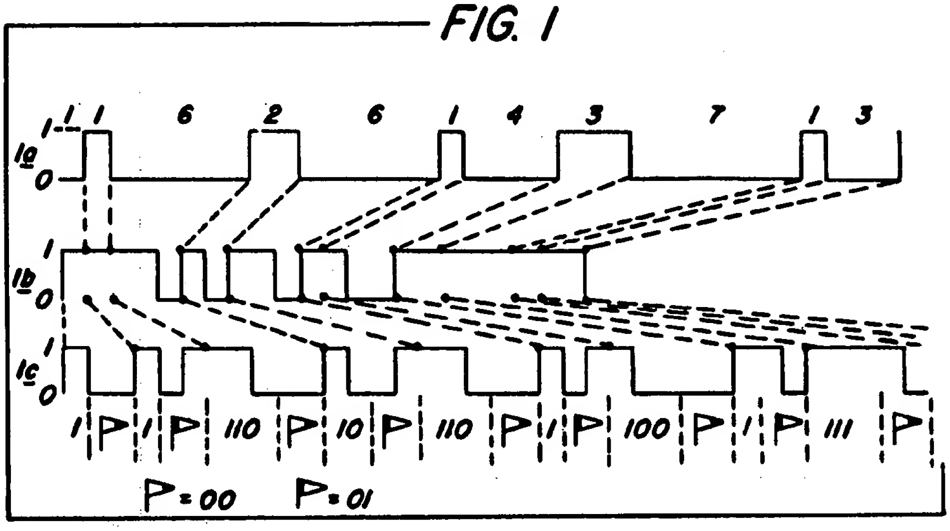


FIG. 1

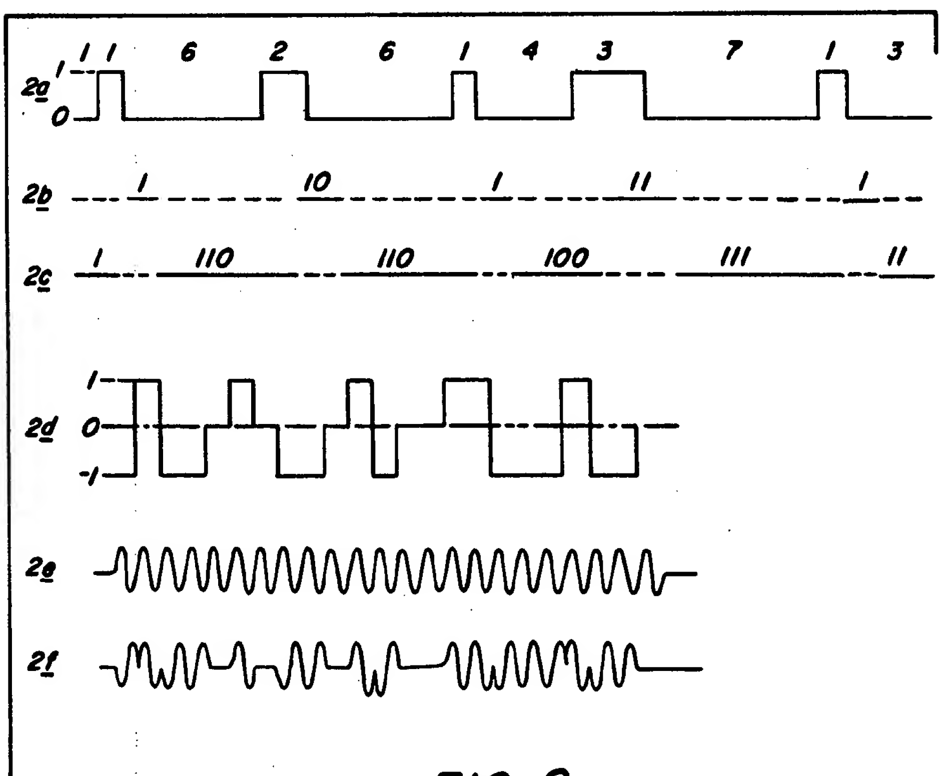


FIG. 2

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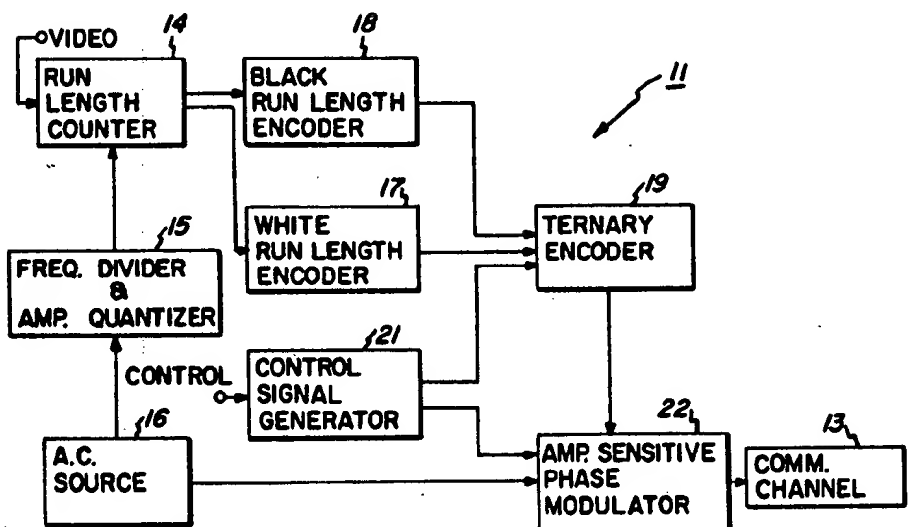
VIDEO
RUN LENGTH COUNTER
14
BLACK RUN LENGTH ENCODER
18
WHITE RUN LENGTH ENCODER
17
11
TERNARY ENCODER
19
FREQ. DIVIDER & AMP. QUANTIZER
15
CONTROL
CONTROL SIGNAL GENERATOR
21
A.C. SOURCE
16
AMP. SENSITIVE PHASE MODULATOR
22
COMM. CHANNEL
13

FIG. 3

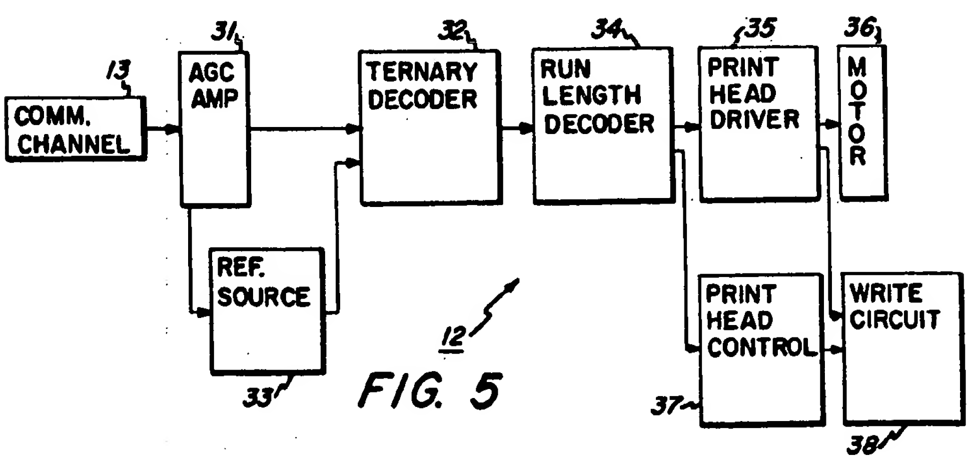
COMM. CHANNEL
13
AGC AMP
31
TERNARY DECODER
32
RUN LENGTH DECODER
34
PRINT HEAD DRIVER
35
MOTOR
36
REF. SOURCE
33
12
PRINT HEAD CONTROL
37
WRITE CIRCUIT
38

FIG. 5

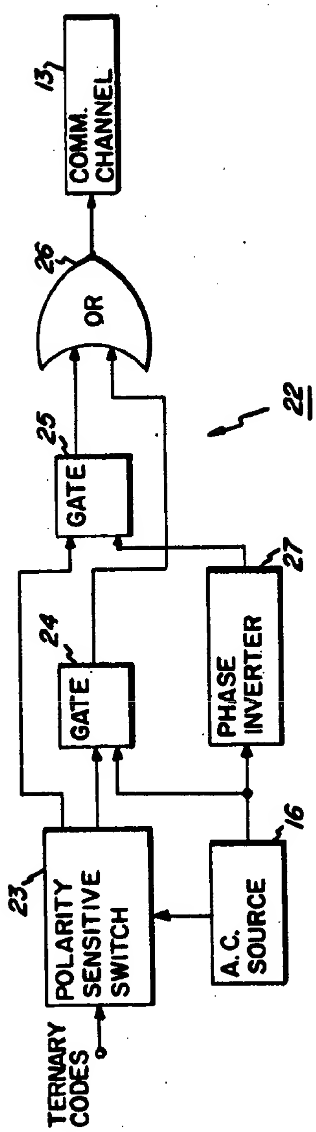

FIG. 4

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RUN LENGTH ENCODING AND DECODING METHODS AND MEANS

BACKGROUND OF THE INVENTION

This invention relates to run length encoding and decoding for raster scanned imaging systems and, more particularly, to methods and means for highlighting the boundaries between serial run length message codes of variable length.

Raster scanned imaging systems often are data rate limited. For example, conventional facsimile systems typically depend on limited bandwith communications channels, such as are provided by the public switched telephone network. Accordingly, to increase the throughput of those systems, substantial effort and expense have been devoted to the development of data compression and decompression techniques for eliminating and then restoring the redundant information that is commonly found in video signals having a raster scan format — viz., signals comprising a predetermined number of serial picture elements for each of a plurality of successive, substantially equidistantly spaced scan lines. Of course, in facsimile systems, throughput is customarily expressed in terms of a document transmission time.

Others have recognized that run length encoding and decoding may be employed in digital raster scanned imaging systems for compressing and decompressing, respectively, binary video signals. In that context, a "run" is classically defined as being an uninterrupted series of picture elements of the same logic level. Thus, run length encoding is utilized to convert the white and/or black runs of a binary video signal having a raster scan format into corresponding run length message codes. Conversely, run length decoding is a complementary process for reconverting those message codes into white and/or black runs of the appropriate length to reconstruct the video signal.

As a general rule, the run length message codes are of variable length (i.e., bit count) to optimize, or at least increase, the data compression. Moreover, the run length message codes are usually serially fed from the encoder to the decoder. Consequently, others have addressed the problem of discriminating between run length message codes of variable length in a serial data stream.

More particularly, it has been suggested that flag codes be inserted into the data stream to separate the run length message codes. That is, however, counterproductive because the additional bits comprised by the flag codes detract from the increased throughput capability offered by the data compression. Another, more sophisticated proposal is to employ mutually exclusive run length message codes so that each code is distinguishable from the prefixes of all other codes. That approach is taken in constructing what are commonly referred to as "Huffman codes", thereby acknowledging D. A. Huffman, "A Method for the Construction of Minimum — Redundance Codes", *Proceedings of the I.R.E.*, September 1952, pp. 1098–1101. A mutually exclusive or Huffman-type code set has substantial merit, but the complexity of the code set rapidly increases as additional codes are added.

SUMMARY OF THE INVENTION

Against the background, an object of this invention is to provide relatively simple and reliable methods and means of discriminating between serial run length message codes of variable length. A more detailed, related object is to provide methods and means for imparting self-identifying boundaries to serial run length message codes of the foregoing type, without resorting to a mutually exclusive code set.

To carry out those and other objects of the present invention, there are black and white run length encoding means for converting a binary video input signal having a raster scan format into binary black and white run length message codes which are preselected so that the initial or lead bit of each of those codes is at a given logic level. Ternary encoding means convert the binary message codes into a series of ternary black and white run length message codes which have distinctive amplitude transitions at any intra-scan line code boundaries, and an amplitude sensitive phase modulator then modulates a carrier signal to provide a phase modulated, interruped carrier passband signal suitable for transmission over a limited bandwidth communications channel. To recover the video signal from the passband signal, the process is reversed.

BRIEF DESCRIPTION OF THE DRAWINGS

Still further objects and advantages of this invention will become apparent when the following detailed description is read in conjunction with the attached drawings, in which:

FIG. 1 illustrates a conventional run length encoding process requiring flag codes;

FIG. 2 illustrates a run length encoding process which takes advantage of the present invention;

FIG. 3 is a simplified block diagram of a facsimile transmitting terminal including a run length encoder constructed in accordance with this invention;

FIG. 4 is a more detailed block diagram of the amplitude sensitive phase modulator shown in FIG. 3, and

FIG. 5 is a simplified block diagram of a facsimile receiving terminal including a complementary run length decoder.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

While the invention is described in some detail hereinbelow with specific reference to a single exemplary embodiment, it is to be understood that there is no intent to limit it to that embodiment. On the contrary, the aim is to cover all modifications, alternatives, and equivalents falling within the spirit and scope of the invention as defined by the appended claims.

Turning now to the drawings, and at this point especially to FIG. 1, it is known that a binary video signal **1a** having a raster scan format can be converted into a series of black and white run length message codes **1b** through the use of a run length encoding process. However, if the message codes are of variable length, the boundaries of the successive codes must be clearly identified.

As previously mentioned, others have proposed that flag codes be inserted between the successive run length codes to identify the code boundaries. For example, white-to-black transitions and black-to-white transitions of the video signal **1a** may be marked by inserting fixed length flag codes "00" and "01", respectively, between the message codes for the picture elements immediately proceeding and succeeding the transitions. The message codes are selected to exclude the bits patterns for the flag codes so that the alternating series of message codes

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and flag codes 1c is capable of being decoded to recover the video signal 1a.

Unfortunately, the flag codes incrementally increase the number of bits necessary to convey the video information as indicated by the following analysis of the encoding process shown in FIG. 1:

Table 1

Color Represented	Run Length	Message Code	Flag Code
White	1	1	00
Black	1	1	01
White	6	110	00
Black	2	10	01
White	6	110	00
Black	1	1	01
White	4	100	00
Black	3	11	01
White	7	111	00
Black	1	1	01
White	3	11	00

In this case, if the message code sequence 1111010110110011111111 is compared against the message code/flag code sequence 1001011100010011100010110000110111100101110O, it will be found that the addition of the flag codes doubles the number of bits in the serial data stream.

Referring to FIG. 2, in accordance with this invention, black and white run length message codes are converted into ternary codes so that intra-scan line code boundaries are marked by distinctive amplitude transitions. As in other run length encoding processes, a binary video input signal 2a having a raster scan format is converted into corresponding black and white run length message codes 2b and 2c, respectively. The initial or lead bits of all of the message codes are selected to be at the same, say, high ("1") logic level, but otherwise the codes need only differentiate between runs of different length. Indeed, the message codes need not even distinguish between black and white runs because plural runs within a given scan line inherently alternate between black and white.

In keeping with the present invention, to serially generate a series of ternary black and white run length message codes 2d having distinctive amplitude transitions at the code boundaries, the bits of the binary message codes 2b and 2c are selectively level shifted relative to a predetermined reference level. More particularly, as shown, the initial bits and all other bits of like logic level (i.e., the high or "1" logic level bits) within the black message codes 2b are translated to a relatively positive level. Conversely, the initial bits and all other bits of like logic level (again, the "1" bits) within the white message codes 2c are translated to a relatively negative level. Furthermore, the other or low ("0") logic level bits of the black and white message codes 2b and 2c are translated to or maintained at the reference level. As a result, the ternary codes 2d make transitions from the negative signal or reference levels to the positive signal level to unambiguously identify white-to-black message code boundaries and from the positive signal or reference levels to the negative signal level to unambiguously identify black-to-white message code boundaries.

Moreover, to carry out this invention, a carrier frequency signal 2e is modulated in accordance with the tenary codes 2d to provide a phase modulated, interrupted carrier passband signal 2f for transmitting the ternary codes over a limited bandwidth transmission channel.

Turning to FIG. 3, there is a facsimile transmitting terminal 11 (shown only in relevant part) which takes advantage of the above-described process to transmit the information content of a subject copy (not shown) to a remote receiving terminal 12 (FIG. 4) via a limited bandwidth communications channel 13.

In keeping with generally accepted practices, a binary video input signal representing the information content of the subject copy is applied to a run length counter 14 which is incremented at a predetermined rate by clock pulses and selectively reset to convert the runs of black (image representing) and white (background representing) picture elements within the video signal into corresponding counts. Specifically, the counter 14 is synchronously reset (by means not shown) as the scanning of the subject copy advances from scan line-to-scan line and asynchronously reset (by means also not shown) in response to each white-to-black and black-to-white intra-scan line transition of the video input signal. To provide the clock pulses for the counter 14, there suitably is a frequency divider and amplitude quantizer 15 for generating clock pulses in response to a carrier frequency signal supplied by an ac. carrier signal source 16.

More or less conventional white and black run length encoders 17 and 18, respectively, are included to serially generate and temporarily store binary white and black run length message codes, respectively, in response to the counts provided by the run length counter 14. The first count for each scan line is applied to the white run length counter 17 in the expectation that at least the first picture element of each scan line will represent white, background information. Thereafter, any subsequent counts are alternately routed so that the second count is applied to the black run length counter 18, the third to the white run length encoder 17, and so forth until the scanning advances to the next scan line. As will be seen, identical code sets may be used for encoding the black and white runs. It is, however, important that the code sets be selected so that the first bit of each message code is at a given logic level.

A ternary encoder 19 alternately reads the binary message codes provided by the white and black run length encoders 17 and 18 and selectively shifts the bits of those codes as previously described to generate a series of ternary white and black run length message codes having distinctive amplitude transitions at the intra-scan line code boundaries. The usual control signals (such as start of scan signals, end of line signals, synchronization pulses, and error detection signals) are inserted into the data stream before and after each scan line of encoded video by a control signal generator 21. A carrier signal supplied by the signal source 16 is then modulated in an amplitude sensitive phase modulator, 22 to provide a phase modulated interrupted carrier passband signal for transmitting the ternary run length message codes and the control signals to the receiving terminal 12 via the communications channel 13.

Referring to FIG. 4 for additional details of the amplitude sensitive phase modulator 22, there is a polarity sensitive switch 23 for selectively enabling and disabling a pair of gates 24 and 25 in response to the ternary codes generated by the ternary encoder 19. The gates 24 and 25 are interposed between the ac. source 16 and separate inputs of an OR circuit 26 which leads to the communication channel 13. A phase inverter 27 is included between the source 16 and the gate 25 so that a positive phase carrier frequency signal is applied to

the gate 24 and a negative phase carrier frequency signal is applied to the gate 25.

The switch 23 is returned through the ac. source 16 to the reference (say, a common ground) for the ternary encoder 19, thereby permitting the switch 23 to discriminate between the positive, negative, and reference levels of the ternary codes. When those codes are positive, the switch 23 enables the gate 24 to feed the positive phase carrier signal into the communications channel 13. On the other hand, when the ternary codes are negative, the switch 23 enables the gate 25 to feed the negative phase carrier signal into the communications channel 13. But, when the ternary codes are at the reference level, both of the gates 24 and 25 are disabled and, therefore, the carrier is interrupted. Accordingly, the passband signal has distinctive phase transitions to identify intra-scan line message code boundaries.

Turning to FIG. 5, at the receiving terminal 12, the passband signal is amplified by an automatic gain controlled amplifier 31 and then demodulated and decoded by a ternary decoder 32. A reference source 33 is triggered in response to a sample of the passband carrier provided by the amplifier 31 to supply a carrier frequency signal which is in phase with the sample. The phase of that signal is compared against the passband signal by the ternary decoder 32 so that a bit of one (here, a high ("1")) logic level is supplied if those two signals are in phase or of opposite phase and of the opposite or low ("0") logic level if the two signals are of unrelated phases. Thus, the decoder 32 relies on the passband phase transitions and the end of line signals (not shown) to gate the bits for binary white and black run length codes to a run length decoder 34 where the binary video signal is reconstructed run length-by-run length.

A print head driver 35 actuates a suitable motor 36 in response to the reconstructed video signal 5*e* to translate a print head (not shown) along successive scan lines of a recording medium (also not shown). Additionally, the reconstructed video signal 5*e* is fed through a print head controller 37 to a print head write circuit 38, whereby the print head is selectively energized to print a replica or "facsimile" of the subject copy on the recording medium. As will be appreciated, the printing takes place as the print head scans in, say, a forward direction. Preferably, the write circuit 38 is blanked by a blanking signal supplied by the print head driver 35 while the print head is retracing or flying back in the opposite or reverse direction.

CONCLUSION

In view of the foregoing, it will now be understood that relatively simple and reliable methods and means have been provided for identifying the boundaries between serial run length message codes. Furthermore, it will be appreciated that the same message codes can, if desired, be used for black and white run lengths, thereby minimizing the number of members required to form a complete code set. Moreover, it will be understood that the presence of the distinctive passband phase transitions at the intra-scan line boundaries of the ternary codes reduces the risk of significant errors being introduced by transmission noise. Indeed, since black and white discriminative information is retained, there is virtually no risk of a run of one sense being inverted to appear as a run of the opposite sense.

What is claimed is:

1. In a limited bandwidth raster scanned imaging system including run length encoding means for converting a binary video signal having a raster scan format into binary black and white message codes, the improvement comprising

ternary encoding means for selectively level shifting said binary message codes to provide a series of ternary black and white run length message codes having one polarity corresponding to initial bits of black message codes, another polarity corresponding to initial bits of white message codes, and a reference level corresponding to other bits of black and white run length message codes; and

amplitude sensitive means for phase modulating a carrier signal in response to ternary codes of said one and said other polarity and the interrupting said carrier signal in response to ternary codes of said reference level, thereby generating a phase modulated, interrupted carrier passband signal.

2. The improvement of claim 1 wherein

said binary run length message codes are of variable length, all of said binary message codes comprise at least an initial bit of a given logic level, and at least some of said binary message codes include at least one additional bit of an opposite logic level.

3. The improvement of claim 2 wherein said run length encoding means generate the same binary message codes in response to black and white runs, respectively, of the same length.

4. In a facsimile system for providing a facsimile copy of a subject copy in response to a binary video signal having a raster scan format; said system including a transmitting terminal, a receiving terminal, and a limited bandwidth communications channel for interconnecting said transmitting and receiving terminals; said transmitting terminal having run length encoding means for converting a binary video signal into binary black and white run length message codes; and said receiving terminal having run length decoding means for recovering said binary video signal from said binary black and white run length message codes; the improvement comprising

ternary encoding means within said transmitting terminal for selectively level shifting said black and white message codes and for interleaving said message codes on a scan line-by-scan line basis to provide a series of ternary black and white run length message codes having any intra-scan line code boundaries marked by distinctive amplitude transitions,

modulating means within said transmitting terminal for phase modulating and selectively interrupting a carrier signal in accordance with said ternary message codes to provide a phase modulated, interrupted carrier passband signal for transmission to said receiving terminal via said communications channel, and

ternary decoding means within said receiving terminal for recovering said binary black and white run length message codes from said passband signal.

5. The improvement of claim 4 wherein

said binary black and white run length message codes are of variable length and each include at least an initial bit of a given logic level, and

said ternary encoding means shifts bits of said black message codes which are at said given logic level to a first level of one polarity, bits of said white message codes which are at said given logic level

to a second level of opposite polarity, and bits of said black and white message codes which are at an opposite logic level to an intermediate reference level, thereby creating distinctive amplitude transitions at intra-scan line the ternary code boundaries.

6. A method for converting a binary video signal having a raster scan format and including picture elements representing background areas and image areas into a data compressed passband signal, said method comprising the steps of

converting runs of background representing picture elements within said video signal into binary white run length message codes,

converting runs of image representing picture elements within said video signal into binary black run length message codes,

interleaving said white and black run length message codes on a scan line-by-scan line basis, starting with a white run length message code for each scan line,

selectively level shifting the interleaved white and black run length message codes to provide a series of ternary black and white run length message codes having distinctive amplitude transitions to identify intra-scan line code boundaries,

phase modulating and selectively interrupting a carrier signal in accordance with said ternary codes to provide a phase modulated, interrupted carrier passband signal.

7. The method of claim 6 wherein

said binary white and black run length message codes are of variable length, but each include at least an initial bit of a given logic level;

said level shifting translates bits at said given logic level of said binary black run length message codes to a first level of one polarity, bits at said given logic level of said binary white run length message codes to a second level of opposite polarity, and any bits of said binary black and white run length message codes which are at an opposite logic level to a third, predetermined reference level intermediate said first and second levels, thereby providing distinctive amplitude transitions at the intra-scan line ternary code boundaries; and

said carrier signal is phase modulated to have one phase in response to ternary message codes of said one polarity and an opposite phase in response to ternary codes of said opposite polarity and is interrupted in response to ternary codes at said reference level.

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